

SIMULTANEOUS AUDITORY DISCRIMINATION

J. M. HARRISON

BOSTON UNIVERSITY

Stimuli in many visual stimulus control studies typically are presented simultaneously; in contrast the stimuli in auditory discrimination studies are presented successively. Many everyday auditory stimuli that control responding occur simultaneously. This suggests that simultaneous auditory discriminations should be readily acquired. The purpose of the present experiment was to train rats in a simultaneous auditory discrimination. The apparatus consisted of a cage with two response levers mounted on one wall and a speaker mounted adjacent to each lever. A feeder was mounted on the opposite wall. In a go-right/go-left procedure, two stimuli were presented on each trial, a wide-band noise burst through one speaker and a 2-kHz complex signal through the other. The stimuli alternated randomly from side to side across trials, and the stimulus correlated with reinforcement for presses varied across subjects. The rats acquired the discrimination in 400 to 700 trials, and no response position preference developed during acquisition. The ease with which the simultaneous discrimination was acquired suggests that procedures, such as matching to sample, that require simultaneous presentation of stimuli can be used with auditory stimuli in animals having poor vision.

Key words: simultaneous auditory stimuli, discrimination, acquisition, asymptotic level, lever press, albino rats

Investigations of visual and auditory stimulus control typically have used different methods throughout their histories, and this difference is reflected in the methods currently used to study auditory discrimination. Visual stimuli generally are presented simultaneously, whereas auditory stimuli are presented in succession in discrimination studies.

Yerkes and Dodson (1908) developed the control (discrimination) box for the study of visual discrimination. A go-right/go-left procedure with simultaneous presentation of two different visual stimuli was used. The stimuli were alternated randomly, side to side, across trials, and the response of approaching the correct stimulus was reinforced. The simultaneous presentation of the two visual stimuli was characteristic of the study of visual discrimination up to Skinner's (1938) popularization of the successive method (Fields, 1928, 1929; Lashley, 1912, 1930; Munn, 1932; Watson & Watson, 1913; Yerkes 1912), and the simultaneous method is still used extensively (e.g., Herman, Hovancik, Gory, & Bradshaw, 1989; Iwai, Yaginuma, & Mishkin, 1986).

In contrast, the two stimuli in auditory discrimination studies are presented in succession. Johnson (1913) trained dogs in a T maze. Auditory stimuli (from two tuning forks) were presented from a table located near the choice point. A go-right/go-left procedure with successive presentation of the stimuli was used. In the presence of a 256-Hz tone entering the left alley was reinforced, and in the presence of a 320-Hz tone entering the right alley was reinforced. Hunter (1914, 1915) extended Johnson's work, and the go-right/go-left procedure with successive stimulus presentation has been used extensively (e.g., Dewson, 1964; Harrison, 1983; Henry, 1936; Lawicka, 1969; Muenzinger & Gentry, 1931; Pennington, 1938; Raslear, 1989; Thuma, 1932). The go/no-go procedure, in which the subject is required to make a response in the presence of one sound and not to respond in the presence of a second sound, has also been used extensively in the study of auditory discrimination (Lawicka, 1964, 1969; Lawicka, Mishkin, & Rosvold, 1975; May, Moody, & Stebbins, 1989; Neill & Harrison, 1987; Shepherd, 1914), and D'Amato and Colombo (1985) developed a go/no-go auditory matching-to-sample procedure.

A number of auditory discrimination experiments have come close to the simultaneous presentation of the two stimuli. Herington and Gundlach (1933) used a T maze in which an

I thank F. Idrobo and H. Marcucella for their useful comments on earlier versions of this manuscript. Correspondence and reprint requests should be sent to J. M. Harrison, Department of Psychology, Boston University, 64 Cummington Street, Boston, Massachusetts 02215.

earphone (used as a speaker) was mounted in the wall at the end of each of the two alleys. They presented each stimulus (600-Hz and 1-kHz tones) twice, in the sequence left-right-left-right during each trial. Neither the duration of each stimulus nor the time between right-left presentations was reported. Briggs (1979) studied squirrel monkeys using an alternating presentation of the stimuli. Her apparatus contained two response levers with a speaker mounted adjacent to each lever. The two auditory stimuli (5-kHz square waves), which differed 15 dB, sound pressure level (SPL) in pressure, were presented in rapid alternation (250 ms on and off), the interval between the onset of one speaker and the offset of the other being about 10 μ s. Responding on the designated correct lever was reinforced. Herman and Gordon (1974) and Herman and Arbeit (1973) investigated matching to sample and learning sets in dolphins. The two stimuli were presented underwater and in succession from two speakers 25 ft apart. Each stimulus was presented for 2.5 s separated by 0.5 s. The dolphin was required to enter a listening area before a trial was initiated.

The literature appears to contain only one experiment (Beach & Herman, 1972) in which the two auditory stimuli were presented simultaneously through two speakers. They used a procedure similar to that of Herman and Arbeit (1973) but presented the two stimuli to the dolphin simultaneously. Although no acquisition or asymptotic performance level data are presented, differential control of a pointing response 6 in. from one of the speakers was obtained.

The go-right/go-left procedure with simultaneous presentation of targets is sometimes used in the investigation of echolocation (see reviews by Nachtigall, 1980, and Schusterman, 1980); however, in these experiments, the echoes occur in sequence because the subjects scan the targets from side to side.

Many acoustic events of everyday environments acquire control of responding. Everyday environments are characterized by a multiplicity of asynchronous sounds, many of which occur at the same time. It is under these conditions that some environmental sound sources gain control of responding. The simultaneous occurrence of two or more sounds is thus the norm rather than the exception under everyday conditions, and this suggests that there is

no intrinsic objection to presenting sounds simultaneously in experimental discriminative tasks. On this basis, it would be expected that subjects would acquire a simultaneous auditory discrimination, and there is no reason to believe that the acquisition and asymptotic performance level would differ from that found in typical visual discrimination studies.

The purpose of the present experiment was to train rats in a simultaneous auditory discrimination analogous to those discrimination procedures in which the visual stimuli are presented simultaneously.

METHOD

Subjects

Three male albino Sprague-Dawley rats, 200 days old at the start of the experiment, were used. They were housed in individual cages with unlimited access to water. Body weights were reduced to and subsequently maintained at 80% of those under ad-libitum feeding conditions.

Apparatus

The apparatus consisted of a wire cloth enclosure (30 cm deep, 35 cm wide, and 30 cm high). Two response levers were mounted symmetrically on one wall 10 cm above the floor and 25 cm apart. A speaker (Radio Shack®, 40-170) was mounted above each lever, and the output of the speaker was conveyed to the vicinity of the adjacent lever by a funnel affixed, with the point facing out, to the front of the speaker. A liquid feeder was attached to the center of the opposite wall 10 cm above the floor of the cage. Sweetened condensed milk, consisting of one part milk to four parts water, was presented in volumes of 0.1 mL for 5 s whenever reinforcers were delivered. A 7.5-W houselight was mounted on the roof of the enclosure. The apparatus was housed in a chamber that was 40 cm deep, 75 cm wide, and 54 cm high. The subject's performance could be observed through a transparent panel in the chamber door.

Two auditory stimuli, previously shown to be localizable and discriminably different when successively presented (Harrison, 1988; Neill & Harrison, 1987), were used. The first stimulus consisted of wide-band noise bursts (0.49 s on, 0.198 s off) that had a continuous spec-

trum of from 4 to 40 kHz. The second stimulus consisted of bursts (0.2 s on, 0.2 s off) of a 2-kHz rectangular signal. This signal produced a picket fence spectrum out to 40 kHz. The acoustic spectra of the two stimuli have been published elsewhere (Neill & Harrison, 1987). The pulse rates of the two stimuli were selected to be different and nonmultiples of each other so that the overlapping of the pulses of the two stimuli continually varied. The level of the sounds was set to 46 dB SPL at the center of the cage using a Radio Shack® sound level meter calibrated with a Bruel and Kjaer pistophone (4220).

To reduce the background noise of the power amplifiers to below the rats' auditory threshold, the speakers were connected to the amplifiers via -20 dB attenuators. Random spikes coming in on the AC line were reduced to near the random noise level of the amplifiers by using a constant voltage transformer (Sola®, type CVS 2) and a line filter (Corcom® 10VR1). Cross talk between the two signals was reduced to the background level by using independent signal paths joined and grounded at only one point.

The noise and rectangular pulses were generated by a Coulbourn Instruments noise generator (S81-02) and voltage controlled oscillator (S25-05), respectively. Each stimulus was gated by two electronic switches (S84-04) connected in series to obtain an off signal level (especially at the higher frequencies) that was at the noise level of the system. The experiment was programmed by an Apple IIe® computer and custom-built interface.

Procedure

Preliminary training. The gating inputs of the electronic switches were disabled throughout preliminary training (i.e., no sounds were presented). Lever pressing was shaped by hand. Each rat received 60 reinforcements distributed over responses on both levers to obtain approximately equal responding on both levers. In subsequent sessions, reinforcement was set up on a variable-interval schedule that was gradually increased to 46 s. Reinforcement was randomly set up (using a probability generator) on either the left or right lever. Responding on the two levers was kept approximately equal by occasionally adjusting by hand the left-right availability of the reinforcer as needed. Preliminary training required nine

sessions. The rats were studied 7 days a week, and a session ended after 40 trials.

Discrimination training. Discrimination training was started in the following session. The electronic switches remained disabled at the start of the session, and the subject was studied for 10 trials to ensure that it was responding normally. A trial started with the offset of the intertrial interval (ITI), which varied around a mean of 46 s, and remained in operation until a single response was made on either lever. Because the electronic switches were disabled, no stimuli were presented during these 10 trials. After these trials, the switches were enabled, and in subsequent trials both stimuli were presented until a response was made on one of the levers. The noise was presented from one side and the 2-kHz signal from the other, with the location of each stimulus alternating randomly from side to side across trials. A single response on the lever adjacent to the stimulus designated S+ was reinforced and the trial terminated. If the rat responded on the lever adjacent to the stimulus designated S-, the trial simply terminated. The stimuli remained on until a response was made. Forty trials constituted a session, and the rats were studied daily. The 2-kHz signal was S+ for Rats 524 and 530 and the noise was S+ for Rat 528.

On the assumption that responding would readily come under the control of the S+, no correction procedure was used, nor was any minimum interval programmed between the occurrence of an ITI response and a trial. No timeout followed an S- response, other than the ITI.

All rats received a sufficient number of sessions to reach what was judged by eye to be the asymptotic level of the percentage of reinforced responses. The percentage of reinforced responses was calculated by dividing the number of reinforced responses by the sum of reinforced and nonreinforced responses and multiplying by 100.

The rats were given two types of stimulus control test sessions. For Rats 524 and 528 the test sessions were given between Sessions 37 and 38, and Rat 530 was tested between Sessions 34 and 35. The purpose of these sessions was to determine the extent to which the S+ and S- controlled responding compared to the absence of both stimuli.

In the S+ test session, the subject received

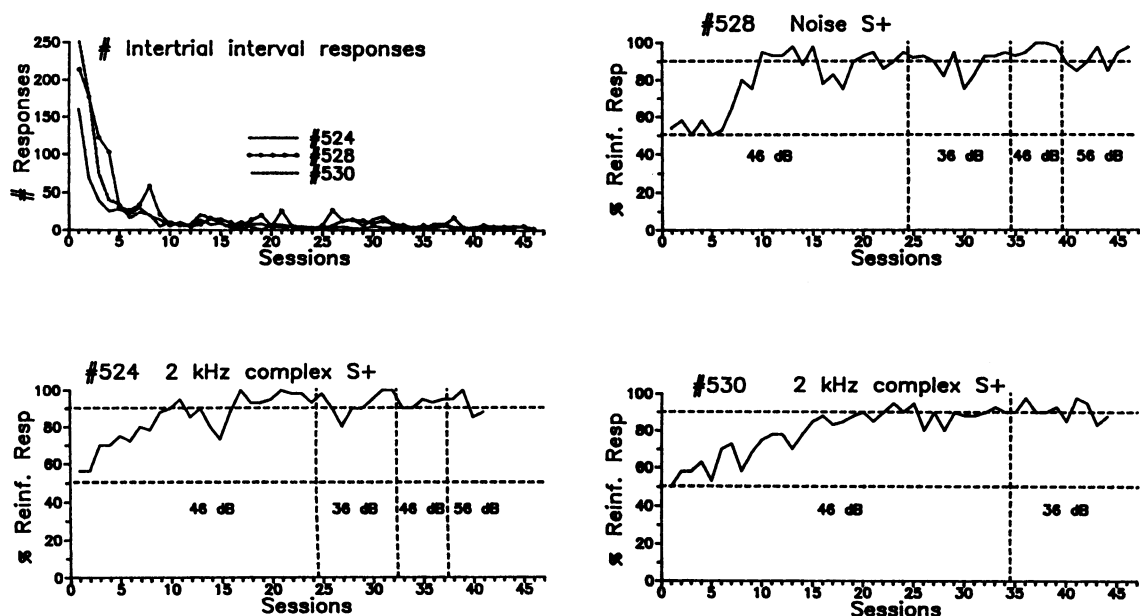


Fig. 1. The top left panel shows the number of intertrial responses per session for all subjects. The remaining three panels show the percentage of reinforced responses per session for the individual rats. The vertical lines indicate the session at which the SPL was changed to the SPL value indicated. The horizontal dashed lines indicate no control (50%) and the 90% criterion value.

10 test trials in which only the S+ was presented. The test trials were distributed randomly in the middle 20 trials of the session, and the side on which the S+ was presented randomly alternated. Responding during the test trials was not reinforced. The S- test session was the same, except that only the S- was presented during the 10 test trials.

RESULTS

The number of ITI responses per session is shown in the upper left panel of Figure 1. The number of responses fell to a low, and asymptotic, level in all subjects by the 10th session. The acquisition of control of responding by the S+ is shown in the leftmost portion of the remaining three panels (labeled 46 dB) of Figure 1. Rats 524 and 528 reached the 90% reinforced response level in 10 sessions (400 trials) and Rat 530 reached the same level in 19 sessions (760 trials). The data suggest that it did not matter which stimulus was designated the S+.

The pressure level of 46 dB used in the experiment seemed a reasonable value to use as a starting level. To check that pressure level

was not a critical variable, the level of both stimuli was reduced 10 dB (to 36 dB) for all subjects without affecting the asymptotic performance level. For Rats 524 and 528, the level was returned to 46 dB and then increased to 56 dB, again without any change in the asymptotic performance level.

The control exerted by the S+ and S-, presented separately, was measured in test sessions. To examine control by S+, the S- was omitted in 10 test trials, randomly distributed in the middle 20 trials of the S+ test session. Test trial responses were not reinforced. Control by S- was examined in the same way by omitting S+ in the 10 test trials. All tests were carried out at 46 dB, SPL. The results are expressed as the number of test trials in which the rat responded on the lever adjacent to the sounding speaker. The results are shown in Table 1.

In S+ test trials, Rats 524 and 528 responded on the lever adjacent to the S+ on 100% of the test trials. This is essentially the same level of responding that occurred for the 30 normal trials of the test session (90% correct responses for Rat 524 and 100% correct responses for Rat 528). Test data were not avail-

Table 1

Percentage of adjacent responses in test trials.

Rat	S+ test	S- test
524	100 (90)	50 (95)
528	100 (100)	90 (100)
530	Not taken	90 (95)

Note: The percentage of reinforced responses for the normal trials of the test sessions is shown in parentheses.

able for the 3rd subject. In S- test trials, Rats 528 and 530 responded on the lever adjacent to the S- in 90% of the test trials. That is, for these 2 subjects there was clear differential control of responding by S-. The 3rd rat (524) responded on the lever adjacent to the S- on 50% of the trials, indicating no differential control by S-.

Response position preference during acquisition (the first 23 sessions) is shown in Figure 2. Position preference was calculated by dividing right lever responses by the total number of responses on both levers, and expressing the number as a percentage. None of the subjects showed a strong or persistent position preference, and the data are characterized principally by decreasing variability across sessions.

DISCUSSION

Stimulus control was obtained readily with no need for the use of a correction procedure, a minimum time interval between a response and a trial onset, or response-initiated trials (on a third lever) that would hold the subject in a fixed position at the onset of each trial. There was also no persistent response position preference. And although the stimuli differed in quality in the present experiment, it did not matter which stimulus was S+.

The results of the S+ test sessions showed that the rats responded in 100% of the trials on the lever adjacent to the sounding (S+) speaker. This result would be expected because the rats responded on the lever adjacent to the S+ in normal sessions and also because the number of responses in the absence of both stimuli (the intertrial interval) was near zero.

It was expected that the subjects would respond predominantly on the lever adjacent to S- in the S- test session because, although the stimuli differed in quality and responding

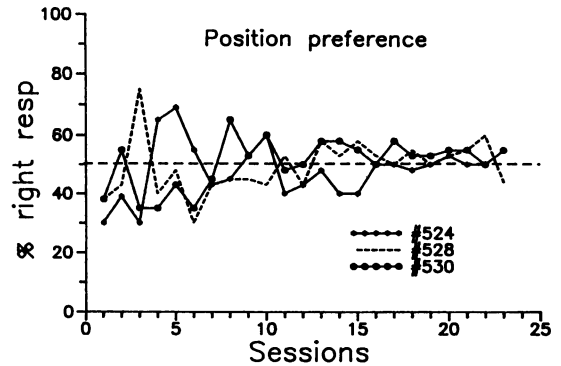


Fig. 2. The percentage of trial responses on the right lever per session. The horizontal dashed line indicates no response position preference.

on the lever adjacent to the sound quality designated S+ was normally reinforced, the stimuli were similar in being localized sound sources and responding was reinforced only in the presence of localized sound sources. In the absence of either stimulus (the ITI) no responses were reinforced. Because responding in the presence of localized sound sources was reinforced and responding in the absence of localized sound sources was not reinforced, it might be expected that the subject would respond on the lever adjacent to a localized sound source, whether that was an S+ or an S- test trial. Responding of Rats 528 and 530 confirmed this analysis; these rats responded on the lever adjacent to the S- in 100% and 90% of the trials, respectively. The reasons S- did not similarly control responding in Rat 524 are not clear.

The ease of training rats in a simultaneous auditory discrimination suggests that procedures requiring the simultaneous presentation of two stimuli, such as matching to sample, can be investigated in species that have poor vision or lack color vision. Just as the visual stimuli have to be appropriate for the subject species in an experiment, so sensory characteristics must be addressed in selecting auditory stimuli. Pure tones (sine waves with slow rise-decay times) should not be used because they are, in general, poor controllers of various aspects of responding in many species, including rats (Harrison & Beecher, 1969), squirrel monkeys (Harrison & Briggs, 1977; Segal & Harrison, 1978), cattle (Heffner, 1981), elephant (Heffner & Heffner, 1982), predators of small birds (Marler, 1955), and humans

(Terhune, 1974). It is essential that the stimuli be localizable. Fay (1988) has published a compendium of the attributes of hearing of a wide range of vertebrate species, and this information is helpful in the design of stimuli to be used in behavioral experiments.

The SPL dimension should probably be avoided in simultaneous discriminations. Briggs (1979), for example, investigated control by SPL difference in squirrel monkeys using the procedure described in the introduction. On each trial the stimuli were presented in rapid alternation at the two response levers. She found more rapid acquisition when the higher level stimulus was S+; that is, stimuli differing along this dimension did not give symmetrical results. The results of S+ and S- test trials also showed that the kind of control that developed in the two training conditions differed. For subjects trained with the higher level stimulus as S+, both stimuli controlled responding on the lever adjacent to the stimulus when each was presented alone. For the other training condition (lower level stimulus S+), each stimulus controlled responding on the lever remote from the speaker sounding the stimulus during test trials.

Although the reason for not using simultaneous stimulus presentation in auditory experiments is not stated, it is possible that considerations of masking mitigated against the use of the method. The spectral content of the two stimuli was the same in the work of Briggs (1979), a condition that would maximize simultaneous and nonsimultaneous masking (Moore, 1982). Measurements by Briggs suggested that there might be complete masking of the lower level stimulus in those trials in which the monkey was near the higher level stimulus at trial onset.

Simultaneous masking would occur in any simultaneous auditory discrimination, but the degree of masking would be lower for stimuli differing in spectral content. This also suggests that the pressure level dimension should be avoided.

The simultaneous auditory discrimination may be thought of as a concurrent go/no-go task on each of the two levers. That is, on the left lever, for example, either the S+ or S- is presented randomly on each trial, and responding when the stimulus is S+ is reinforced. Neill and Harrison (1987) studied the acquisition and asymptotic level of responding

in rats using a single-lever go/no-go procedure. The speaker was adjacent to the lever, and the stimuli were the same as those used in the present experiment. There was no differential control of responding by the two stimuli for the first two sessions for 2 of the subjects, and there was weak differential control for the first session for the 3rd. The degree of differential control reached an asymptotic level in 10 sessions for 2 subjects and eight sessions for the 3rd. These data suggest that an asymptotic level of performance might be reached in about 10 sessions in the present experiment. Subjects 524 and 528 of the present experiment clearly fit this suggestion, whereas Rat 530 was slower than might be expected.

The relatively high level of control by S- in the present experiment and the Neill and Harrison (1987) study is most likely due to the adjacency of the S- to the response sites. Harrison (1988) used a go/no-go procedure in which the stimulus not correlated with reinforcement occurred randomly with respect to S+. The stimulus not correlated with reinforcement exerted no control of responding at any time in acquisition when it was presented through a remote speaker and the S+ was presented through an adjacent speaker. However, when both stimuli were presented through an adjacent speaker, control by the negative stimulus was similar to that reported by Neill and Harrison.

REFERENCES

- Beach, F. A., III, & Herman, L. M. (1972). Preliminary studies of auditory problem solving and intertask transfer by the bottlenose dolphin. *Psychological Record*, **22**, 49-62.
- Briggs, R. (1979). *Simultaneous auditory intensity discrimination in monkeys*. Unpublished doctoral dissertation, Boston University, Boston, MA.
- D'Amato, M. R., & Colombo, M. (1985). Auditory matching-to-sample in monkeys (*Cebus apella*). *Animal Learning & Behavior*, **13**, 375-382.
- Dewson, J. H., III. (1964). Speech sound discrimination by cats. *Science*, **144**, 555-556.
- Fay, R. R. (1988). *Hearing in vertebrates*. Winnetka, IL: Hill-Fay Associates.
- Fields, P. E. (1928). Form discrimination in the white rat. *Journal of Comparative Psychology*, **8**, 143-158.
- Fields, P. E. (1929). The white rat's use of visual stimuli in the discrimination of geometrical figures. *Journal of Comparative Psychology*, **9**, 107-122.
- Harrison, J. M. (1983). Effects of age on some behavioral characteristics of novel auditory stimuli in the rat. *Experimental Aging Research*, **9**, 35-39.

- Harrison, J. M. (1988). Control of responding by sounds of different quality: An evolutionary analysis. *Journal of the Experimental Analysis of Behavior*, **50**, 521-539.
- Harrison, J. M., & Beecher, M. D. (1969). Control of responding by the location of an auditory stimulus: Rate of rise time of the stimulus. *Journal of the Experimental Analysis of Behavior*, **12**, 217-227.
- Harrison, J. M., & Briggs, R. M. (1977). Orientation and lever responding in auditory discriminations in squirrel monkeys. *Journal of the Experimental Analysis of Behavior*, **28**, 233-241.
- Heffner, R. S. (1981). Sound localization and the superior olivary complex in horses and cattle. *Journal of the Acoustical Society of America*, **69** (Suppl.), S10. (Abstract)
- Heffner, R. S., & Heffner, H. E. (1982). Hearing in the elephant (*Elephas maximus*): Absolute sensitivity, frequency discrimination, and sound localization. *Journal of Comparative and Physiological Psychology*, **96**, 926-944.
- Henry, F. M. (1936). Audition in the white rat: II. The learning of a pure tone discrimination. *Journal of Comparative Psychology*, **22**, 105-121.
- Herrington, G. B., Jr., & Gundlach, R. H. (1933). How well can guinea pigs and cats hear tones? *Journal of Comparative Psychology*, **16**, 287-303.
- Herman, L. M., & Arbeit, W. R. (1973). Stimulus control and auditory discrimination learning sets in the bottlenose dolphin. *Journal of the Experimental Analysis of Behavior*, **19**, 379-394.
- Herman, L. M., & Gordon, J. A. (1974). Auditory delayed matching in the bottlenose dolphin. *Journal of the Experimental Analysis of Behavior*, **21**, 19-26.
- Herman, L. M., Hovancik, J. R., Gory, J. D., & Bradshaw, G. L. (1989). Generalization of visual matching by a bottlenosed dolphin (*Tursiops truncatus*): Evidence for invariance of cognitive performance with visual and auditory materials. *Journal of Experimental Psychology: Animal Behavior Processes*, **15**, 124-136.
- Hunter, W. S. (1914). The auditory sensitivity of the white rat. *Journal of Animal Behavior*, **4**, 215-222.
- Hunter, W. S. (1915). The auditory sensitivity of the white rat. *Journal of Animal Behavior*, **5**, 312-329.
- Iwai, E., Yaginuma, S., & Mishkin, M. (1986). Acquisition of discrimination learning of patterns identical in configuration in macaques (*Macaca mulatta*). *Journal of Comparative Psychology*, **100**, 30-36.
- Johnson, H. M. (1913). Audition and habit formation in the dog. *Behavior Monographs*, **2**(3, Serial No. 8).
- Lashley, K. S. (1912). Visual discrimination of size and form in the albino rat. *Journal of Animal Behavior*, **2**, 310-331.
- Lashley, K. S. (1930). The mechanism of vision: I. A method for rapid analysis of pattern-vision in the rat. *Journal of Genetic Psychology*, **37**, 453-460.
- Lawicka, W. (1964). The role of stimuli modality in successive discrimination and differentiation learning. *Bulletin de l'Academie Polonaise des Sciences*, **12**, 35-38.
- Lawicka, W. (1969). Differing effectiveness of auditory quality and location cues in two forms of differentiation learning. *Acta Biologica Experimentalis*, **29**, 83-92.
- Lawicka, W., Mishkin, M., & Rosvold, H. E. (1975). Dissociation of deficits on auditory tasks following parietal prefrontal lesions in monkeys. *Acta Neurobiologiae Experimentalis*, **35**, 581-607.
- Marler, P. (1955). Characteristics of some animal calls. *Nature*, **176**, 6-8.
- May, B., Moody, D. B., & Stebbins, W. C. (1989). Categorical perception of conspecific communication sounds by Japanese macaques, *Macaca fuscata*. *Journal of the Acoustical Society of America*, **85**, 837-847.
- Moore, B. C. J. (1982). *Introduction to the psychology of hearing* (2nd ed.). New York: Academic Press.
- Muenzinger, K. F., & Gentry, E. (1931). Tone discrimination in white rats. *Journal of Comparative Psychology*, **12**, 195-205.
- Munn, N. I. (1932). An investigation of color vision in the hooded rat. *Journal of Genetic Psychology*, **40**, 351-362.
- Nachtigall, P. E. (1980). Odontocete echolocation performance on object size, shape and material. In R. G. Busnel & J. F. Fish (Eds.), *Animal sonar systems* (pp. 71-95). New York: Plenum Press.
- Neill, J. C., & Harrison, J. M. (1987). Auditory discrimination: The Konorski quality-location effect. *Journal of the Experimental Analysis of Behavior*, **48**, 81-95.
- Pennington, L. A. (1938). The function of the brain in auditory localization: IV. Method of training and control experiments. *Journal of Comparative Psychology*, **25**, 195-211.
- Raslear, T. G. (1989). Discriminability, loudness, and masking in the rat (*Rattus norvegicus*): A confirmation and extension. *Journal of Comparative Psychology*, **103**, 289-296.
- Schusterman, R. J. (1980). Behavioral methodology in echolocation by marine mammals. In R. G. Busnel & J. F. Fish (Eds.), *Animal sonar systems* (pp. 11-41). New York: Plenum Press.
- Segal, M., & Harrison, J. M. (1978). The control of responding by auditory stimuli: Interactions between different dimensions of the stimuli. *Journal of the Experimental Analysis of Behavior*, **30**, 97-106.
- Shepherd, W. T. (1914). On sound discrimination by cats. *Journal of Animal Behavior*, **4**, 70-75.
- Skinner, B. F. (1938). *The behavior of organisms*. New York: Appleton-Century.
- Terhune, J. M. (1974). Sound localization ability of untrained humans using complex and sinusoidal sounds. *Scandinavian Audiology*, **3**, 115-120.
- Thuma, B. D. (1932). The response of the white rat to tonal stimuli. *Journal of Comparative Psychology*, **13**, 57-86.
- Watson, J. B., & Watson, M. I. (1913). A study of the responses of rodents to monochromatic light. *Journal of Animal Behavior*, **3**, 1-14.
- Yerkes, R. M. (1912). The discrimination method [Note]. *Journal of Animal Behavior*, **2**, 142-144.
- Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, **18**, 459-482.

Received December 4, 1989
Final acceptance March 7, 1990